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August Weismann, painted by Otto Scholderer in 1896.

EVOLUTIONARY BIOLOGY

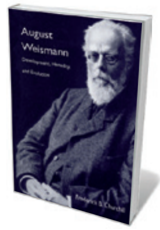
Paean to a founder of heredity

Jane Maienschein applauds a study of towering nineteenth-century biologist August Weismann.

A monumental study of an important but surprisingly little-studied biologist, *August Weismann* represents half a century of scholarly investment by historian of science Frederick Churchill. Churchill immersed himself in the observations and experiments, people, institutions and ideas of the nineteenth and early twentieth centuries — an astoundingly fertile era for the biological sciences — as well as in all of the many books and articles that Weismann (1834–1914) wrote, in German and English.

That anybody can write this kind of book these days is awe-inspiring. When Churchill was my PhD supervisor in the 1970s, he warned me not to take on too large a dissertation topic, given the dearth of jobs and the pressures to move results into print quickly. The history of science is richer for his not having heeded his own advice.

Weismann's great contribution was the idea that germ-plasm — the name that he gave to the essential element of gametes, or eggs and sperm — carries the material of heredity from one generation to the next, unaffected by the environment. Germ-plasm theory, which Weismann set out in the 1880s, rejected the possibility that acquired characteristics can be inherited, as propounded by Jean-Baptiste Lamarck in the early nineteenth century. Weismann's materialistic view of life provided a new understanding of biology, in which natural selection occurred between individual organisms, as Charles Darwin held, and with competition at the level of inherited determinants. This influenced the nature of the resulting variations. So Weismann, as Churchill makes clear, had one foot in the observational traditions and questions of nineteenth-century natural history — even as he extended the other into the experimental, theoretical twentieth century.



August Weismann: Development, Heredity, and Evolution
FREDERICK B. CHURCHILL
Harvard Univ. Press: 2015.

August Weismann reveals a scientist who grew up fascinated by nature and worked briefly as a medical doctor, then adjusted to roles as a faculty member at the University of Freiburg in Germany and director of its zoological institute, where he spent most of his career. Weismann looked at butterfly variations in considerable detail to explore patterns of heredity, protozoa to get at reproduction, jellyfish-like hydromedusae, the planktonic crustaceans *Daphnia*, and frogs — whatever it took to study the relevant phenomena. In 1862, while living at the isolated Schaumburg Palace as personal physician to Archduke Stephan of Austria for a year, he also explored natural history, especially of insects. The experience reinforced Weismann's determination to pursue biological research rather than medicine, and he moved to Freiburg, where he took on a series of research positions.

He increasingly turned to microscopy, experimental embryology and cytology to look deep into an organism to see changes in the cells and nucleus. At the Freiburg zoological institute, Weismann relied on his own observations and those of his students and assistants — both in the spirit of collaboration and to compensate for his failing eyesight.

Throughout, Weismann insisted that development, heredity and evolution are interconnected and must be studied as such. As he saw it, biologists should seek the underlying chemical and physical mechanisms. So while his contemporaries focused on details of cells, chromosomes or evolutionary mechanisms, ▶

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Weismann sought to illuminate the links between them.

Churchill shows how Weismann's experimental observations of chromosome movements during cell division reinforced his germ-plasm theory. Weismann adapted ideas from leading cytologists and experimental embryologists such as Theodor Boveri and Wilhelm Roux, to link heredity and development through what Churchill calls his "architectonic view". Instead of a holistic or vitalistic understanding of the organism, Weismann developed a more structural view in which the system depends on integration of the material parts, with guidance from the germ-plasm and its determinants. Development then constructs the organism out of cells, with reproduction providing a source of variation on which natural selection acts, enabling evolution.

Weismann was confident and sometimes controversial. Churchill shows how disagreements helped Weismann to work out his own ideas. He sparred, for example, with physician and biologist Rudolf Virchow over issues of acquired characteristics and the role of external factors in shaping variation. And Weismann clashed with zoologist Theodor Eimer about the apparent randomness of evolution. Dozens of leading scientists influenced or interacted with Weismann because of his central role in biology. The zoologist and illustrator Ernst Haeckel, for example, was a close friend, but his views diverged from Weismann's in ways that influenced both men, and affected public perceptions of biology. We also see the impact on Weismann of technically brilliant figures such as Boveri and theoreticians including Darwin. Weismann in turn influenced his contemporaries and subsequent generations of Darwinians.

Even as his contemporaries began to specialize and to give up the study of connections between heredity, development and evolution in favour of specialized study of the parts or selected processes, Weismann worked hard to develop a comprehensive understanding of life. Churchill has mirrored that determination in developing a compelling and comprehensive understanding of Weismann, his ideas, work, life, contemporaries and context. ■

Jane Maienschein *is Regents', President's and Parents Association Professor at Arizona State University in Tempe, and adjunct senior scientist at the Marine Biological Laboratory in Woods Hole, Massachusetts. Her most recent book is* Embryos Under the Microscope.
e-mail: maienschein@asu.edu

The hybrid dinosaur *Indominus rex* runs rampant in *Jurassic World*.

Q&A Jack Horner

The dinosaur doctor

Montana palaeontologist Jack Horner has served as scientific adviser on the Jurassic Park *films from the start. With the latest,* Jurassic World*, soon to be released, he talks about a shark-devouring* Mosasaurus*, breeding chickens back into dinosaurs and the influence of the film franchise on his own field.*

How did you get involved in the series?
In the early 1990s, a colleague called me and said, "You're in a book about cloning dinosaurs" — Michael Crichton's *Jurassic Park* (Alfred A. Knopf, 1990). I said, "I hope my character doesn't get eaten." I never bothered to pick it up; I am dyslexic and have trouble enough keeping up with my own science. Then director Steven Spielberg called and asked whether I wanted to work on the film. I thought growing a dinosaur was an intriguing idea, and I still do. It is a little far-fetched now, but I think one day we will be able to do it, not using amber-trapped DNA, but through genetic modification of dinosaurs' closest living relatives, birds.

What did work on *Jurassic Park* (1993) entail?
My job was to find things that were obviously wrong. In one scene, the puppeteers were having trouble getting an animatronic *Tyrannosaurus rex* leg to move properly. So I stepped in to control the joystick, making the foot land on its toes in a bird-like position, rather than heel-first like a mammal. In a kitchen scene, the puppeteers had velociraptors sticking out forked tongues, which dinosaurs did not have. Instead, we had the raptors snort to fog up the window, revealing that they had warm blood.

What are the innovations in *Jurassic World*?
The science has got ahead of the films, but we cannot really change the way the dinosaurs look. If suddenly the raptors had feathers, it would destroy consistency. But I did help to render new creatures. You can see a mosasaur, a giant swimming reptile, shoot up from a tank to eat a great white shark. From my research, I helped to ensure that the juvenile triceratops, with its backward-curving horns, looked distinct from the adult, whose horns curve forward. But my biggest job was helping to create the 'genetically modified' *Indominus rex*, a combination of several dinosaurs and other animals, which turns against its makers.

How plausible is such a dino-hybrid?
Jurassic World is set in the future. If you can clone a dinosaur, you can modify its DNA and combine it with that of other animals. We

TOP: UNIVERSAL PICTURES/AMBLIN ENTERTAINMENT; LEFT: MUS. OF THE ROCKIES